Principal Modes of Precipitation Variability from Preliminary Series of IMERG Data

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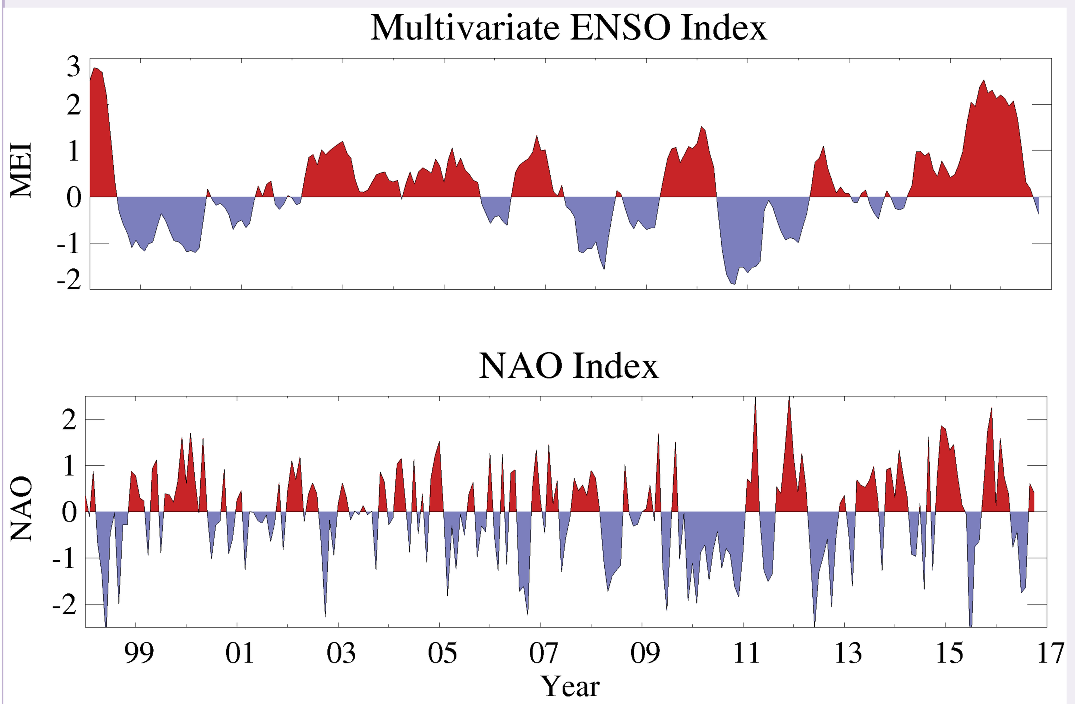
INTRODUCTION

- The Integrated **M**ulti-satellit**E** **R**etrievals for the **G**lobal Precipitation Measurement (GPM) mission, "**IMERG**", is the unified U.S. algorithm that provides merged Microwave/Infrared (IR) satellite precipitation product for the U.S. GPM team.
- Even though **IMERG** record is still very short, 2014-2016, it is tempting to test if it captures ENSO and NAO signals as compared to the popular, still on-going, **T**RMM **M**ulti-satellite **P**recipitation **A**nalysis, **TMPA**.
- El Niño Southern Oscillation (**ENSO**) is the most significant mode of interannual variability of tropical ocean/atmosphere.
- North Atlantic Oscillation (**NAO**) impact is on monthly scales and is mostly an atmospheric mode in the North Atlantic.



- There exist well-defined, multivariate, indexes that represent **ENSO** and **NAO** conditions and phase.

Figure 1. Multivariate **ENSO**, and **NAO** indexes, for the time range of TMPA

DATA AND METHOD

- Monthly IMERG "Final" stitched with "Late" for maximum time coverage
- Monthly TMPA stitched with monthly Near-Real-Time TMPA series for the same coverage as IMERG.
- All data reduced to 1x1 deg resolution;
- Singular Value Decomposition into Normalized Principal Components (PC) , and Empirical Orthogonal Functions (EOF).

If **F** is monthly time series of precipitation in S-mode [time,position], then:

$\mathbf{C}^T\mathbf{F}^T\,\mathbf{F}\mathbf{C} = \Lambda$	**C** = EOF, Λ = Eigen Values
$\mathbf{C}^T\mathbf{C} = \mathbf{I}$	**I** = Identity matrix
$\mathbf{A} = \mathbf{F}\,\mathbf{C}$	**A** = principal components
$\mathbf{A} = \Phi\,\mathbf{D}$	Φ = normalized principal components
	D = diagonal matrix with elements $\sqrt{\lambda_i}$

Note:

$\mathbf{F} = \Phi\,\mathbf{D}\,\mathbf{C}^T$ Reconstruction of original series

$\mathbf{C}\,\mathbf{D}^T = \mathbf{F}^T\,\Phi$ EOF are actually spatial patterns, representing projections of the original time series onto PC, process known as "homogenous correlation maps" because of the apparent regression. For a particular PC, the corresponding EOF reveals the spatial distribution of this mode of variability.

ABBREVIATIONS

GPM	- Global Precipitation Mission		
IMERG	- Integrated **M**ulti-satellit**E** **R**etrievals for the **G**lobal Precipitation Measurement	NAO	- North Atlantic Oscillation
ENSO	- El Niño Southern Oscillation	TRMM	- Tropical Rainfall Measuring Mission
MEI	- Multivariate ENSO Index	TMPA	- TRMM **M**ulti-satellite **P**recipitation **A**nalysis

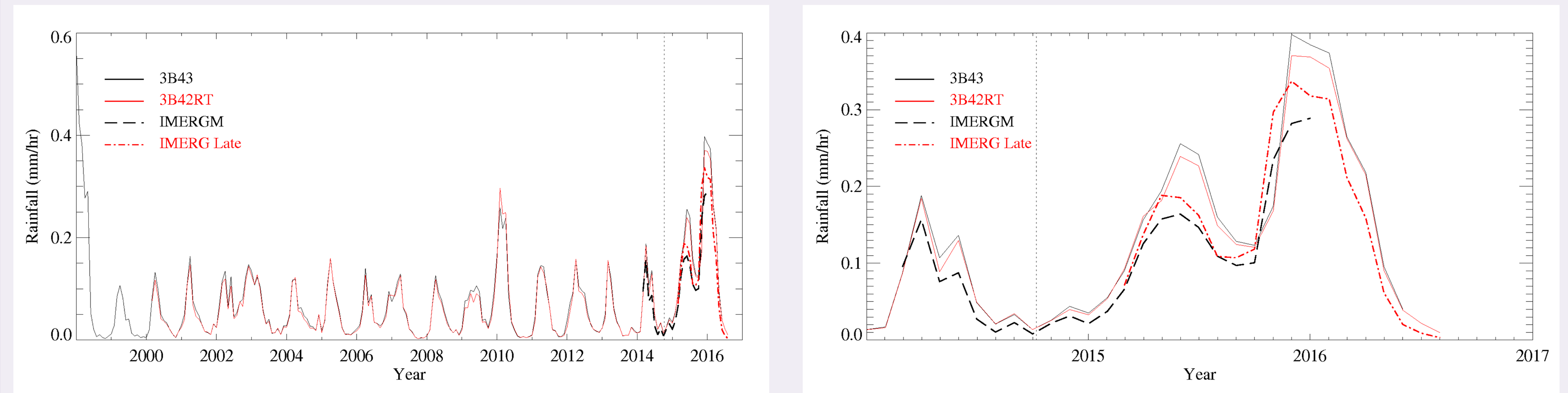


Figure 2. Area-Average of precipitation in Niño 3.4 region. This simple area-average implies it can be expected that IMERG and TMPA will respond well to ENSO even in the short 2014-2016 time period.

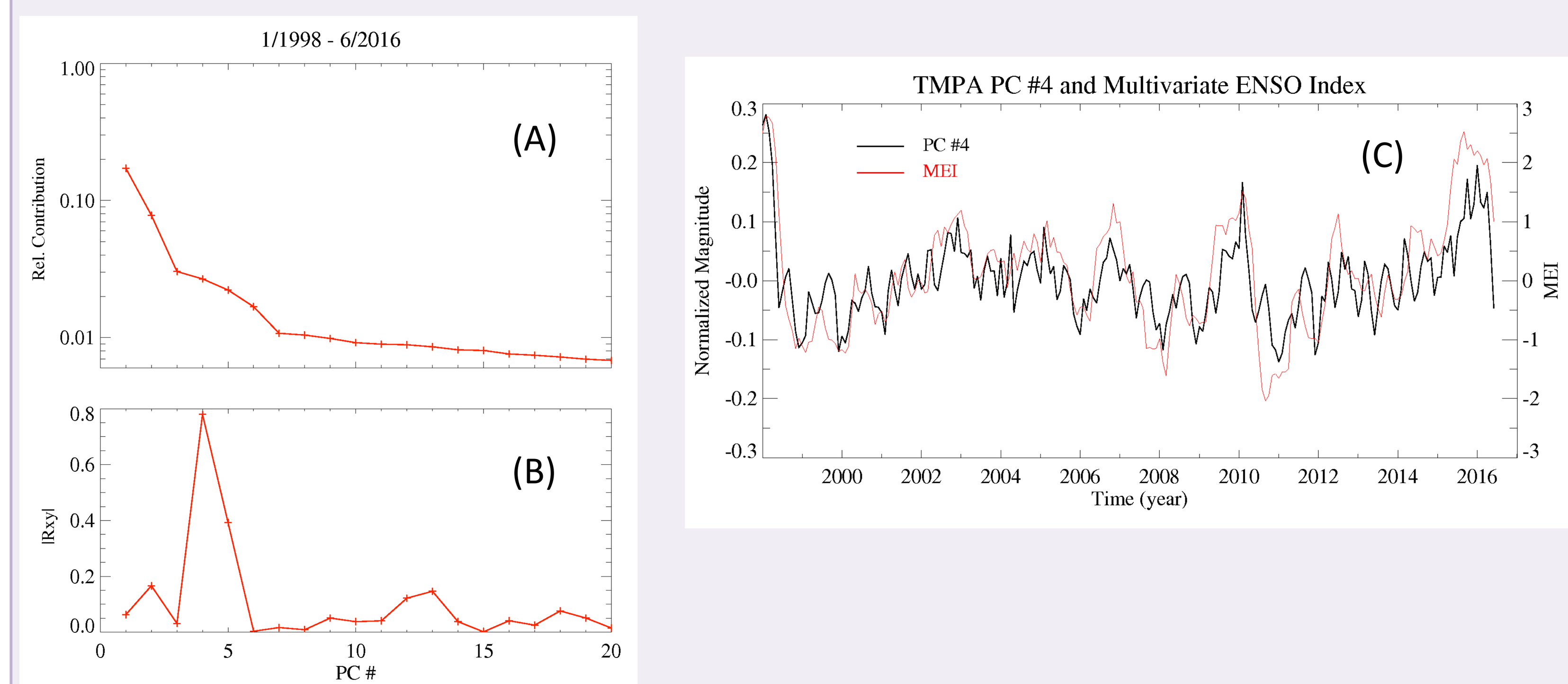


Figure 3. (A) Eigen values, (B) Linear regression of the first 20 (out of 220) Principal Components on **MEI**, and (C) PC4 overplot with MEI, all from **TMPA** full-series. TMPA have excellent response to ENSO, concentrated at PC4-5. The regression of TMPA principal components on MEI can be as strong as 0.8 (PC4), and (C) is the relevant visual demonstration of the strong correlation.

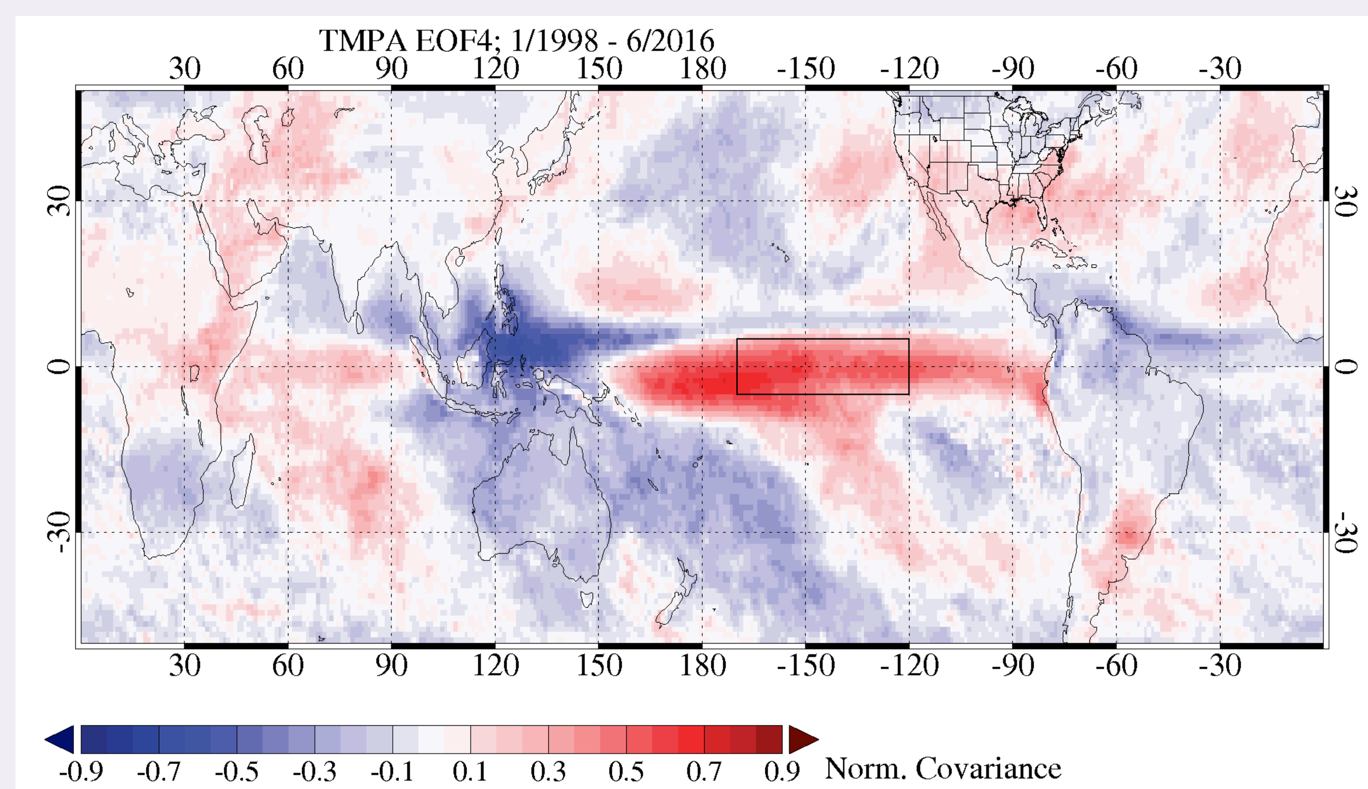


Figure 4. EOF4 spatial pattern of full-series **TMPA**, scaled to represent normalized covariance of PC4 and the time series. This mode alone would suffice to characterize impacts of ENSO on global precipitation.

SUMMARY 1

- TMPA is known for its excellent global response to ENSO
- IMERG shows distinctive response to ENSO even from the short time series, similar to TMPA.
- As TMPA descendant and when extended into TRMM epoch, IMERG is very likely to contain same or improved information content on global impacts of ENSO on precipitation.

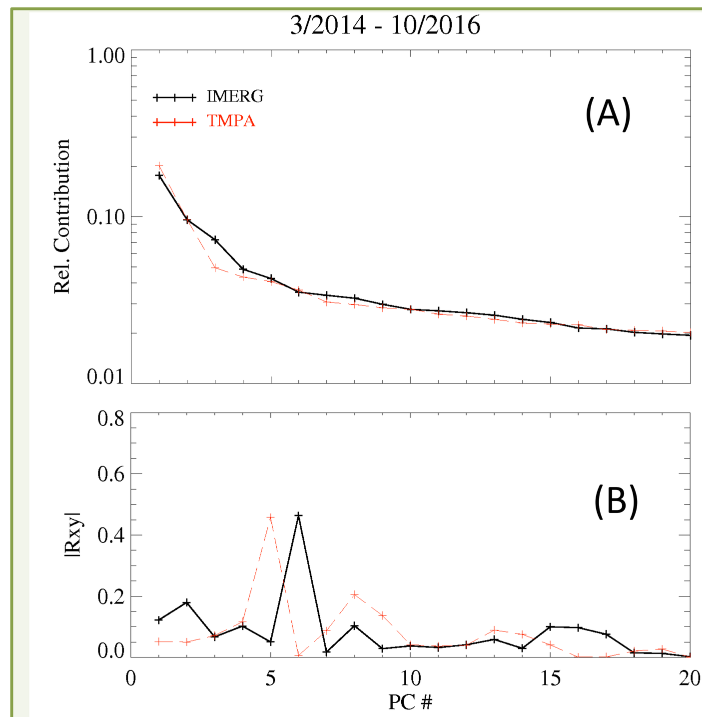


Figure 5. IMERG, and TMPA cut to the same time range (same degrees of freedom); (A) Eigen values; (B) Linear regression of Principal Components on MEI.

ENSO signal is not concentrated in one mode alone, but still distinct even though the degrees of freedom are 1/10 of those in Figure 3-4.

(3/2014 -8/2016)

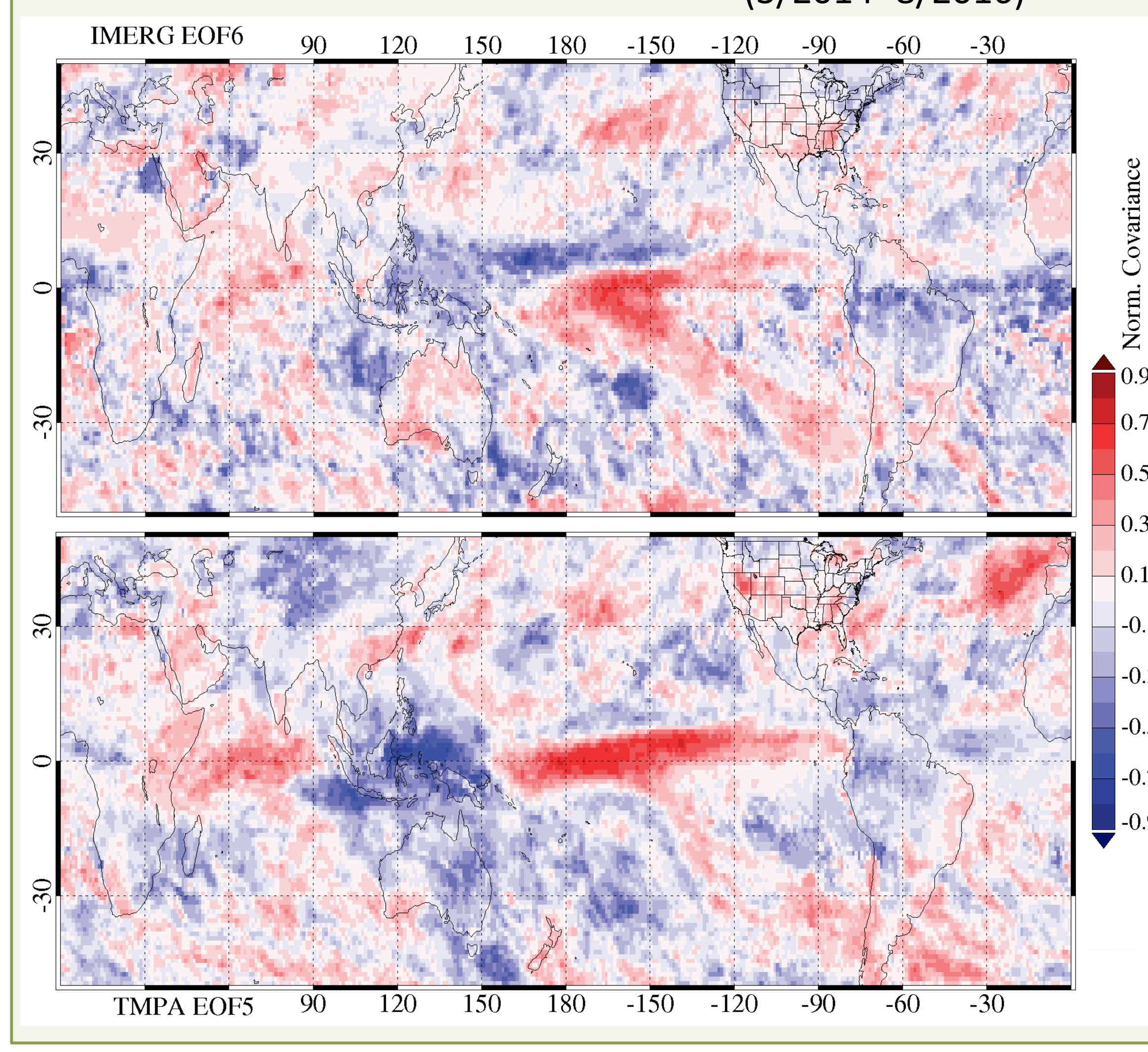


Figure 6. Spatial patterns of IMERG EOF6, and TMPA EOF5, at IMERG time cutoff.

In general, IMERG EOF6 agrees with TMPA EOF5 in where in the past two years ENSO was driving precipitation variability (Central Pacific).

However, inconsistencies (e.g. monsoon regions of Arabian Sea, and North America) are warning that using one mode alone will bring about uncertain results. Reconstruction from several modes should be considered.

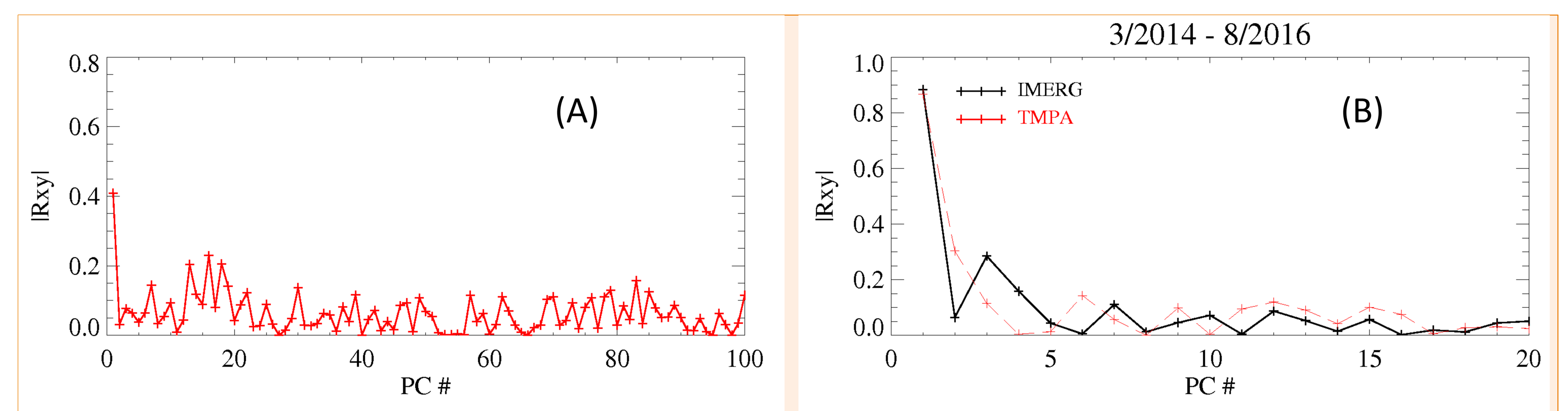


Figure 7. Linear regression of **NAO** on the Principal components of (A) Full-time series of TMPA, and (B) IMERG, and TMPA at IMERG time cutoff.

NAO has inherently seasonal character. In the past 2 years it manifested almost pure seasonal variability (**Figure 1**), which explains the strong correlation with the seasonal PC1.

The rest of the NAO-related variability is spread in PC10-20 (A), and has very low global impact. It cannot be revealed from short series, (B).

SUMMARY 2 (continued)

NAO-driven precipitation variability is spread over multitudes of modes. Studying NAO impacts requires reconstruction from these modes (TMPA modes PC10-20).

Currently, the 30 months of IMERG are not sufficient to extract effects of NAO on precipitation with high confidence.